The Korean Journal of Quaternary Research
Vol. 17, No. 2, pp. 105~108 (2003)

Analyses of Firing Conditions of Ceramics from the Neolithic Age to the Chosun Period in Korea

Sook-Chung Shin

Wonju Museum of Yonsei University, Wonju 220-710, Korea

Introduction

Ceramics are made from viscous clay by molding, drying and firing it. Therefore ceramics do include the wares that are unglazed or glazed and fired once or twice. Korean potteries were produced over the Ages of Neolithic, Bronze, and Iron Age throughout the periods of the Three Kingdoms, United Shilla, Koryo and Chosun. In such periods there appeared potteries that were fired harder at a higher temperature.

The process and technique of pottery production, especially firing temperature, are often subjects of curiosity as firing pottery at a higher temperature would mean progress in production process. In order to study those subjects the writer(and coworkers) made approximately 20 cases of ceramic analysis, in consequence of which various interesting facts were detected. Based on the findings the writer herein suggests some new opinions, different from what is known so far regarding ceramic production process. Following are the summaries of the analyses with the consequences.

Material and Methods

1. Objects of Analyses

In order to look into pottery production process and technical growth and infer the provenance, the properties of ceramics were divided into technical and physical categories.

	Technical properties	Physical properties
Raw material	Clay Tempering material Slip Paint	Color Porosity Hardness Strength Specific gravity etc.
Production process	Molding method Finish treatment Firing	

2. Methods used for Ceramics Analyses

Most physical properties of ceramics such as color, hardness, strength, etc. can be observed by the naked eye. Therefore, studies were naturally focused on materials-e.g. what sort of clay and tempering material were used, where the materials were brought from; and production process such as firing atmosphere - whether oxidizing or reducing - and firing temperature.

Many different analysis methods were used for the identification of such issues. Generally speaking, petrological analysis is used for mineralogical analysis. XRD analysis makes possible clay mineral analysis and firing temperature analysis at the same time. Also, as for

the chemical analysis to detect components and quantities of elements contained in ceramic material, various analysis methods such as AA, NAA, XRF are adopted. To figure out firing temperature, thermal analyses such as DTA, TGA and TEA etc. are used.

SEM scanning electron microscope) is used for the analysis to figure out the whole aspects of firing, and xeroradiography, to see molding process.

The analysis methods most frequently in use in Korean archeology are petrological analysis and XRD (X-ray diffraction). Petrological analysis is used to observe thin sections of ceramics by the use of polarizing microscope whereby the size of mineral, shape, and particles arrangement, ratios and organizations can be detected. Sometimes this analysis enables the identification of surface treatment, slip and paint as well. It further enables the estimation of firing temperature based on the kinds of decomposing mineral and also provides provenance information. As such, petrological analysis is considered the most basic ceramics analysis method.

XRD analysis utilizes the properties of each crystal mineral i.e. its specific diffraction angles and intensities of diffracted ray. If a ceramic ware is ground into powder and the powder is let pass through diffracted X-ray, the position of crystal face of each mineral can be read and thereby the kind of mineral can be detected. If the ceramic ware was fired at a certain degree of, or even higher, temperature, the crystal structure of the clay mineral destroyed at a lower temperature cannot be read. Using such properties, ceramics firing temperature is figured out. For example, Kaolinite that always falls under the prehistoric age breaks at 550C. If the mineral is not readable by the use of XRD, it is supposed that the ceramic ware was fired at a temperature higher than 550℃.

As seen in the tables following hereunder, there are various minerals that help figure out firing temperature.

Results

The Cases of Ceramics Analysis in Korean Archeology

Including approximately 20 cases done by the colleagues and the writer, there are many cases of the prehistoric ages' ceramic analysis performed in Korea, and the number keeps increasing at present. Here introduced are the cases extracted from those, that are of some interest, or that justify to suggest new opinions.

Conclusion

Summaries of the consequences of the analyses and new opinions to be suggested

The Neolithic Age: The raw material used in the production of ceramics and firing temperature were similar to those of the Bronze Age, and so was firing technology as well.

Raw material of ceramics: Kaolinite, illite, chlorite, montmorillonite, mixed layer were evenly used, i.e. all these constituents were well mixed. Coming into the Iron Age there appeared ceramics of silt. In other words soft clay replaced viscous clay. According to the development of production technique, quartz became homogeneous tempering material, and only small quantities were used.

Ceramics firing temperature apparently progressed as an age (period) got into another.

The Neolithic Age-the Bronze Age: 550-800℃ degrees

Plain hard pottery of the Iron Age: 900℃ degrees

The Age of Three Kingdoms: Over 1000℃ degrees in consideration that mullite and crystobalite were detected. The Chosun Period:Around 1100℃ degrees

The length of time between the Age of Three Kingdoms and the Chosun Period is approximately 700 years,

The Neolithic Age:

Area	Analysis Method	Consequences (identified)
Amsa-Dong	Petrographic Analysis XRD	Asbestos, talc, mica quartz, montmorillonite
Misa-Ri	XRD Petrographic Analysis Geological Analysis	Quartz, amphibole, microline etc. Illite Firing temperature is estimated to be 550-800℃ due to absence of kaolinite and illite. The provenance of basic clay is presumed to be piedmont around Misari; to be direct, soil of weathered rock in Paldang area.
Ilsan	XRD Petrological Analysis Geological analysis	Quartz, feldspar, mica, illite, chlorite were detected. Firing temperature: 500-800℃ Provenance of clay: Juyeob palaelsoil around sites.

The Bronze Age

Area	Analysis Method	Consequences
Hwangseok-Ri	Ultra-sonic Washing XRD, EDAX Petrological analysis Firing shrinkage	There are two kinds of red burnished pottery, i.e. one is red color was painted prior to firing and the other, after red color was painted, refiring. The principal constituent of red paint is Fe2 O3. 30 to 40% content of quartz, feldspar, mica is contained. Firing temperature is estimated to be 700-750℃.
Misa-Ri	DTA, NAA, PCA XRD	Calcite, illite and 18 kinds of trace elements were detected. Firing temperature: 550-800℃.
Ilsan	XRD Petrological analysis Geological analysis	Quartz, feldstar, mica, mixed layer, chlorite, hornblend Firing temperature: 550-800℃. Production method is similar to that of the Neolithic Age.
Songkuk-Ri	XRF, XRD, SEM EDS PCA	A large quantity of iron, quartz, sericite, microcline, orthoclase. Montmorillonite were identified. Red pottery and plain pottery have different elements; whether SiO2, Fe2O3, MgO are contained or not makes the difference. Red paint is 40 μ thick. Firing temperature: 750-800℃.
South Han river basin	Petrological analysis XRD PIXE DTA	Basic clay: Mixed layer and weathered clay of kaolinite. Quartz There was a likelihood that ceramics was re-fired after red painting. Likelihood that potters wheel was used in view of the arrangement of particles in rows. Firing temperature: 550-850℃.

The Iron Age

Area	Analysis Method	Consequences
Jodo Kosung Province	Rockwells hardness XRD Refiring NAA	Hardness analysis: The ceramics from this area are classified into three groups (mixed, soft and hard). Soft ceramics : Firing temperature to be 740-800℃. Hard ceramics : Firing temperature to be at 1100℃ or higher. 13 major elements and 18 trace elements were detected.
Ilsan	XRD Petrological analysis Geological analysis	Quartz and a small quantity of feldspar. Silt was used as basic flesh.
North Han river basin	XRD Petrological analysis	Firing temperature: Over 900℃ in consideration that tridymite was detected. Value of vickers' hardness: 30-40 (2 3 by Moh's scale)

The Era Three Kingdoms

Area	Analysis Method	Consequences
Seungju Daegok-Ri Naksu-Ri	XRD Petrological analysis Chemical analysis	Quartz, feldspar, clay material and mullite were detected. Firing temperature is estimated to be over 970℃ in view of mullite peak.
Hapchun Dam (Nopo-Dong, Jeopo-Ri, etc.)	AA, NAA Mossbauer spectroscopy XRD Refiring Chemical analysis	Black patterns of ceramics were painted in carbonaceous material. Quartz, feldspar, clay material, mullite, crystobalite peak were detected. Firing temperature: 900-1200℃.

The Chosun Period

Area	Analysis Method	Consequences
Kwangju in Kyeongki Province, Hakdong-Ri	SEM, XRD, DTA-TGA Dilatometric analysis Chemical analysis KSL properties analysis	14 major elements were detected: kaolinite, quartz, feldspar Iron was detected Bloating caused by magnesium was excessive: Firing for a comparatively short period of time at a high temperature. Firing temperature: around 1100℃ or higher.

but the difference between the firing temperatures of the two Ages is comparatively small. It is presumed that biscuit firing (unglazed) potteries would have been fired at 1100-1200℃ at highest.

Red burnished pottery of the Bronze Age can be divided into two groups. Some ceramic wares were fired once and then painted; and some other wares were painted in red color after first firing and then re-fired. It means that it is very likely that some potteries were re-fired without being glazed.

Potter's wheel may have been used in Korea's Bronze Age. Until now it was known that potter's wheel had been used in the Iron Age and thereafter, but the time when potter's wheel was introduced in Korea can be adjusted to an earlier Age. Only the question as to which type of wheel was used, fast wheel or slow wheel etc., needs to be clarified. More data will have to be collected for the study of this question.